Conjunctive Management and Groundwater Storage

Conjunctive management is the coordinated operation of surface water storage and use, groundwater storage and use, and conveyance facilities. Although surface water and groundwater are sometimes considered to be separate resources, they are connected by the hydrologic cycle. Conjunctive management allows surface water and groundwater to be managed in an efficient manner by taking advantage of the ability of surface storage to capture and temporarily store storm water and the ability of aquifers to serve as long-term storage.

Groundwater Recharge

Groundwater recharge is the movement of surface water from the land surface, through the topsoil and subsurface, and into de-watered aquifer space. Recharge occurs naturally from precipitation falling on the land surface, from water stored in lakes, and from creeks and rivers carrying storm runoff. Recharge also occurs artificially from water placed into constructed recharge ponds (also called spreading basins), from water injected into the subsurface by wells, and from surface storage releases into creeks and rivers beyond what occurs from the natural hydrology (for example, by releases of imported water). Significant amounts of artificial recharge can also occur either intentionally or incidentally from applied irrigation water and from water placed into unlined conveyance facilities. Groundwater banking is the recharge (often of imported surface water or local flood water) into de-watered aquifer space for later recovery and use or exchange with others.

There are three primary components to a conjunctive management project. The first is to recharge groundwater when surface water is available to increase groundwater storage. In some areas this is accomplished by reducing groundwater use and substituting it with surface water, allowing natural recharge to increase groundwater storage (also called in-lieu recharge). The second component is to switch to groundwater use in dry years when surface water is scarce. The third component is to have an ongoing monitoring program to evaluate and allow water managers to respond to changes in groundwater, surface water, or environmental conditions that could violate management objectives or impact other water users. Together these components make up the conjunctive management project.

Other topics in the Water Plan that are related to conjunctive management include the strategies on Groundwater Remediation / Aquifer Remediation, Recharge Areas Protection, Water Transfers, and System Reoperation.

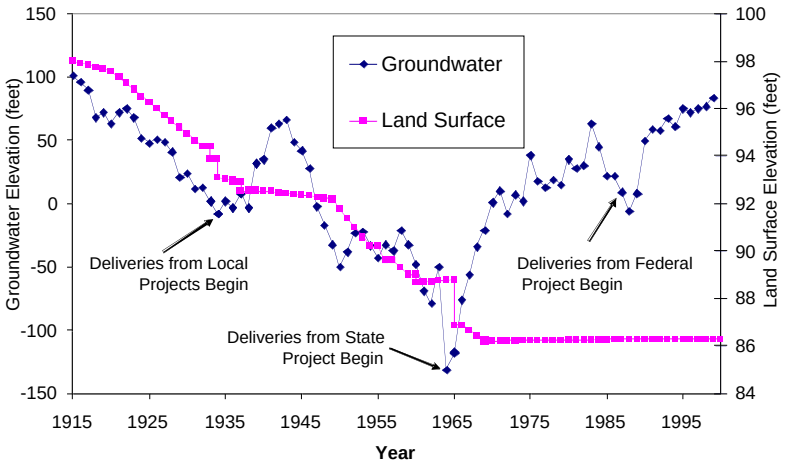
Current Conjunctive Management in California

Conjunctive management has been practiced in California to varying degrees since the Spanish mission era. The first known artificial recharge of groundwater in California occurred in southern California during the late 1800's and is now used as a management tool in many areas. Two examples illustrate the types of conjunctive management underway on a regional and local scale. In Southern California, including Kern County, conjunctive management has increased average year water deliveries by over 2 million acre-feet (AGWA, 2000). Over a period of years, artificial recharge in these areas has increased the water currently in groundwater storage by approximately 7 million acre-feet.

Santa Clara Valley Water District releases local supplies and imported water into more than 20 local creeks for artificial instream recharge and into more than 70 recharge ponds to recharge a total of about 157 thousand acre-feet annually. Conjunctive management has virtually stopped land subsidence caused

by heavy groundwater use and has allowed groundwater levels to recover to those of the early 1900s (see Figure 1).

Figure 1. Relationship between Groundwater Elevations and Land Subsidence in Santa Clara County

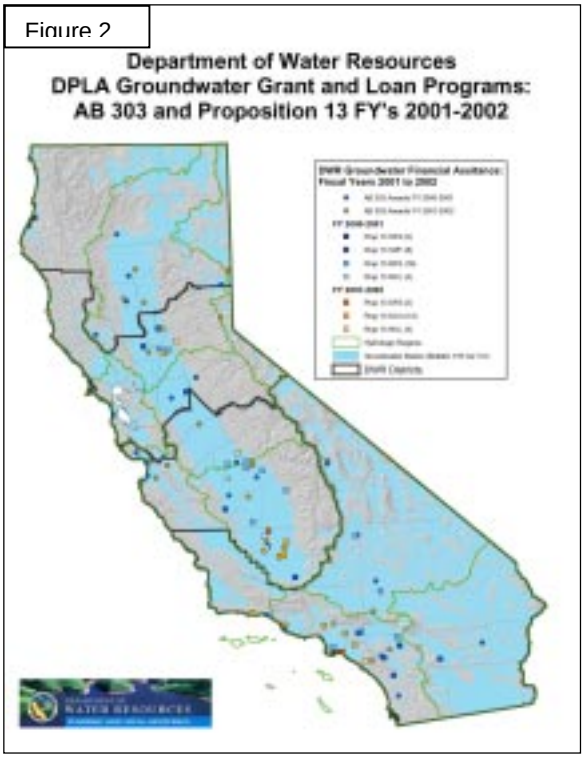


While comprehensive statewide data on the planning and implementation of conjunctive management at the local agency level is not available, DWR's Conjunctive Water Management Program provides an indication of the types and magnitude of projects that water agencies are currently pursuing. The program has awarded over $130 Million in grants and loans for project funding and study throughout California in fiscal years 2001 and 2002 (see Figure 2).

Potential Benefits from Conjunctive Management

Conjunctive management is implemented to improve water supply reliability, to reduce groundwater overdraft and land subsidence, to protect water quality, and to improve environmental conditions. Conservative estimates1 of additional implementation of conjunctive management indicate the potential to increase average annual water deliveries throughout the state by 500 thousand acre-feet with about 9 million acre-feet of "new" groundwater storage. New storage includes both reoperation of existing groundwater storage and recharging water into currently de-watered aquifer space. More aggressive estimates from screening level studies indicate the potential to increase average annual water deliveries by 2 million acre-feet with about 20 million acre-feet of new storage.

Figure 2



The potential benefits from additional conjunctive

[1] Information in this section was derived from five sources: 1) Proposition 13 Groundwater Storage Applications to DWR for fiscal year 2001-2002, 2) A 2000 report by the Association of Groundwater Agencies entitled, "Groundwater and Surface Water in Southern California", 3) A 1998 report by the Natural Heritage Institute entitled, "Feasibility Study of a Maximal Program of Groundwater Banking", 4) A 2002 report by the Natural Heritage Institute entitled, "Estimating the Potential for In-Lieu Conjunctive Management in the Central Valley", 5) A 2002 report by the U.S. Army Corps of Engineers report entitled, "Conjunctive Use for Flood Protection". Methodology for obtaining these estimates is presented in Volume 4.

management are highly dependent on adequate water quality and the ability to capture, convey, and recharge surface water. The above estimates are based on increases in local water deliveries from individual projects with project specific sources of recharge supply and do not necessarily reflect a statewide increase in supply reliability. An increase in statewide supply reliability only occurs when the individual projects use water that would otherwise not be used by other water users or that is needed for regulatory requirements such as water quality, fish and wildlife, and navigation. The more aggressive estimates are based on assumptions that require major reoperation of existing surface water reservoirs and groundwater storage to achieve the benefits and do not fully consider the conveyance capacity constraints for exports from the Delta and other conveyance facilities. Expanding existing or developing new storage or conveyance infrastructure can increase the flexibility and ability to conduct conjunctive management projects. It is also possible to reoperate the existing system and to improve the underlying operational conditions to overcome these constraints.

In addition to water supply benefits, conjunctive management can provide environmental benefits when recharge basins are designed to be compatible with wildlife habitat, such as using natural floodplains and wetlands as recharge areas. Re-operation of surface water storage and use conjunctively with groundwater storage and use can avoid impacts to aquatic species by allowing better management of instream flow and water quality conditions.

Conjunctive Management Case Example Orange County Groundwater Replenishment System

The Groundwater Replenishment (GWR) System is a groundwater management and water supply project jointly sponsored by the Orange County Water District (OCWD) and Orange County Sanitation District (OCSD). The project will take highly treated urban wastewater and treat it to beyond drinking water standards using advanced membrane purification technology. The water will be used to expand an existing underground seawater intrusion barrier by injecting the water into the groundwater basin along the coast. Extraction wells located throughout the basin will draw potable water for municipal and industrial uses.

The GWR System will provide many benefits to Orange County and California.

- Supplements existing water supplies by providing a new, reliable, high-quality source of water to recharge the Orange County Groundwater Basin and protect the basin from further degradation due to seawater intrusion.
- Reduces the amount of treated wastewater released into the ocean and delays the need for another ocean outfall.
- Decreases reliance on imported water from northern California and the Colorado River.
- Helps drought-proof Orange County using a locally-controlled project.
- Reduces mineral build up in Orange County's groundwater by providing a new source of ultra-pure water to blend with other sources, including imported water.
- Uses about half the energy of imported water supplies.

Implementation of the GWR System will be phased. The current schedule calls for Phase 1 of the proposed project to produce up to 72,000 acre-feet per year (AF/yr) of recycled water for groundwater recharge to begin operation in 2007. The total cost of the project is estimated to be $453 Million. The unit cost of the supply is $516.00 per acre-foot.

Potential Costs of Conjunctive Management

Grant applications from DWR's fiscal year 2001-2002 Conjunctive Water Management Program show project costs ranging from $10 to $600 per acre-foot of increase in average annual delivery. The wide range of costs is due to many factors including project complexity, regional differences in construction costs, availability and quality of recharge supply, intended use of water, and treatment requirements. In general, urban uses can support higher project costs than agricultural uses. The average project cost of all applications received by DWR is $110 per acre-foot of increase in average annual delivery. This average unit cost translates to total implementation costs of approximately $1.3 billion for the more conservative level of implementation. While these cost estimates are specific to projects evaluated by DWR, they provide a good indication of implementation costs statewide. The cost of implementing the more aggressive level of conjunctive management is unknown.

Major Issues Facing Additional Conjunctive Management

The major issues facing conjunctive management are:

Lack of Data

There is rarely a complete regional network to monitor groundwater levels, water quality, land subsidence, or the interaction of groundwater with surface water and the environment. Data is needed to evaluate conditions and trends laterally over an area, vertically at different depths, and over time. Also, there is often a reluctance of individuals who own groundwater monitoring or supply wells to provide information or allow access to collect additional information. The result is that decisions must be made with only approximate knowledge of the "true" system. This uncertainty can make any change in operation of groundwater storage unpredictable and controversial.

Infrastructure and Operational Constraints

Physical capacities of existing storage and conveyance facilities are often not large enough to capture surface water when it is available in wet years. Operational constraints may also limit the ability to use the full physical capacity of facilities. For example, permitted export capacity and efforts to protect fisheries and water quality in the Delta often limit the ability to move water to groundwater banks south of the Delta.

Surface Water and Groundwater Management

In California, water management practices and the water rights system treat surface water and groundwater as two unconnected resources. In reality, there is often a high degree of hydrologic connection between the two. Under predevelopment conditions many streams received dry weather base flow from groundwater storage, and streams provided wet weather recharge to groundwater storage. Water quality and the environment can also be influenced by the interaction between surface water and groundwater. Failure to understand these connections can lead to unintended impacts. For example, studies by the University of California, Davis indicate that long term groundwater pumping in Sacramento County has reduced or eliminated dry season base flow in sections of the Cosumnes River with potential impacts to riparian habitat and anadromous fish.

In California, authority is separated among local, state and federal agencies for managing different aspects of groundwater and surface water resources. Several examples highlight this issue: 1) SWRCB regulates surface water rights dating from 1914, but not rights dating before 1914; 2) SWRCB also regulates groundwater quality, but not the rights to use groundwater; 3) County groundwater ordinances and local

agency groundwater management plans often only apply to a portion of the groundwater basin, and those with overlapping boundaries of responsibility do not necessarily have consistent management objectives;4) Except in adjudicated basins, individuals have few restrictions on how much groundwater they can use, provided the water is put to beneficial use on the overlying property. Failure to integrate water management across jurisdictions makes it difficult to manage water for multiple benefits and provide for sustainable use including the ability to identify and protect or mitigate potential impacts to third parties, ensure protection of legal rights of water users, establish rights to use vacant aquifer space and banked water, protect the environment, recognize and protect groundwater recharge and discharge areas, and protect public trust resources. The Protecting Recharge Areas and Urban Runoff Management strategies describe how land use planning can affect groundwater recharge.

Water Quality

Groundwater quality can be degraded by naturally occurring or human introduced chemical constituents, low quality recharge water, or chemical reactions caused by mixing water of differing qualities. Protection of human health, the environment, and groundwater quality are all concerns for programs that recharge urban runoff or reclaimed/ recycled water. The intended end use of the water can also influence the implementation of conjunctive management projects. For example, agriculture can generally use water of lower quality than needed for urban use, but certain crops can be sensitive to some constituents like boron. New and changing water quality standards and emerging contaminants add uncertainty to implementing conjunctive management projects. In some cases, conjunctive management activities may need to be coordinated with groundwater clean up activities to achieve multiple benefits to both water supply and water quality.

Environmental Concerns

Environmental concerns related to conjunctive management projects include potential impacts on habitat, water quality, and wildlife caused by shifting or increasing patterns of groundwater and surface water use. For example, floodwaters are typically considered “available” for recharge. However, flood flows serve an important function in the ecosystem. Removing or reducing these peak flows can negatively impact the ecosystem. A key challenge is to balance the instream flow and other environmental needs with the water supply aspects of conjunctive management projects. There may also be impacts from construction and operation of groundwater recharge basins and new conveyance facilities.

Funding

There is generally limited funding to develop the infrastructure and monitoring capability for conjunctive management projects. This includes funding to develop and implement groundwater management plans, to study and construct conjunctive management projects, and to track, both statewide and regionally, changes in groundwater levels, groundwater flows, groundwater quality (including the location/spreading of contaminant plumes), land subsidence, changes in surface water flow, surface water quality, and the interaction and interrelated nature of surface water and groundwater.

Recommendations to Help Promote Additional Conjunctive Management

The following recommendations are for the state to facilitate conjunctive management:

1. Encourage the development of regional groundwater management plans. Local water management agencies should coordinate with other agencies that are involved in activities that might affect long term sustainability of water supply and water quality within the basin or adjacent to the basin. Such

regional coordination will take different forms in each area because of dissimilar political, legal, institutional, technical, and economic constraints and opportunities. Regional groundwater management plans should be developed with assistance from an advisory committee of stakeholders to help guide the development, educational outreach, and implementation of the plans.

2. Continue funding for local groundwater monitoring and management activities and feasibility studies that enhance the coordinated use of groundwater and surface water. Additional monitoring and analysis is needed to track, both statewide and regionally, changes in groundwater levels, groundwater flows, groundwater quality (including the location/spreading of contaminant plumes), land subsidence, changes in surface water flow, surface water quality, and the interaction and interrelated nature of surface water and groundwater. There is a need to develop comprehensive data on existing, proposed, and potential conjunctive management projects throughout the state and identify and evaluate regional and statewide implementation constraints including availability of water to recharge, ability to convey water from source to destination, water quality issues, environmental issues, and costs and benefits.
3. Give priority for funding and technical assistance to conjunctive management projects that are conducted in accordance with a groundwater management plan, increase water supplies, and have other benefits including the sustainable use of groundwater, maintaining or improving water quality, and enhancing the environment. In addition, allow funding for projects that make use of wet season / dry season supply variability, not just wet year/dry year variability.
4. Assess groundwater management throughout the state to provide an understanding of how local agencies are implementing actions to use and protect groundwater, an understanding of which actions are working at the local level and which are not working, and how state programs can be improved to help agencies prepare effective groundwater management plans.
5. Improve coordination and cooperation among local, state, and federal agencies with differing responsibilities for groundwater and surface water management and monitoring to facilitate conjunctive management, to ensure efficient use of resources, to provide timely regulatory approvals, to prevent conflicting rules or guidelines, and to promote easy access to information by the public.
6. Encourage local groundwater management authorities to manage the use of vacant aquifer space for artificial recharge and to develop multi-benefit projects that generate source water for groundwater storage by capturing water that would otherwise not be used by other water users or the environment. For example, through reservoir reoperation, water recycling and reuse, and water conservation.
7. Work with wildlife agencies to streamline the environmental permitting process for the development of conjunctive management facilities, like recharge basins, when they are designed with pre-defined benefits or mitigation to wildlife and wildlife habitat.

Information Sources

- Association of Groundwater Agencies (AGWA). "Groundwater and Surface Water in Southern California." October 2000.
- CALFED. Common Assumptions, Conjunctive Use Inventory. In progress.
- CALFED. "Conjunctive Use Site Assessment – Draft Report". December 23, 1999
- *Fleckenstein, J.H., Anderson, M, Fogg, G.E. & Mount, J.* (2003), Managing Surface water-groundwater to restore fall flows in the Cosumnes River, Journal of Water Resources Management and Planning, in press.
- Natural Heritage Institute. "Designing Successful Groundwater Banking Programs in the Central Valley". 2000.
- Natural Heritage Institute. "Estimating the Potential for In-Lieu Conjunctive Water Management in the Central Valley". February 2002.
- Natural Heritage Institute. "The Hydrogeological Suitability of Potential Groundwater Banking Sites in the Central Valley". September 2001.
- Natural Heritage Institute. "Feasibility Study of Maximal Program of Groundwater Banking." December 1998.
- SWRCB. "Water Transfer Issues in California: Final Report to the California State Water Resources Control Board by the Water Transfer Workgroup". June 2002.
- U.S. Army Corps of Engineers. Conjunctive Use for Flood Protection. January 2002.